IIFDT PROJECT MILESTONES AND RELATED JPDO-IDENTIFIED NEEDS

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The world-wide aviation industry and governments in many countries, including the United States of America, have determined that future safe, secure, efficient, and environmentally responsible flight requires a significantly different approach to aviation infrastructure, procedures, and operations than that of the current day system. In 2003 the Vision 100 – Century of Aviation Reauthorization Act was enacted by the U.S. Congress and a congressional mandate was issued to create the Joint Planning and Development Office (JPDO), whose purpose is to guide and support the creation of this Next Generation Air Transportation System (NextGen) within the United States.

Under NextGen, the JPDO envisions a future air transportation system that removes many of the constraints in our current system, supports a wider range of operations, and thus delivers an overall system capacity up to three times that of current operating levels. The concept requires a shift in the historical model of air transportation from a system based on established physical/technology infrastructure and the capabilities of service providers to a system that is flexible and adaptable to the varied needs and capabilities of its users. This concept also requires that safety be considered and predicted during design, constantly assessed during implementation through prognostic data analysis, and maintained through an effective safety culture.

To develop and achieve the benefits of NextGen, it is anticipated that new automation, infrastructure, processes, collaboration, and operating concepts based on extensive information sharing will be required. With respect to flight deck operations, the roles and responsibilities of flight deck system[1] agents (i.e. either human or automated) will need to be transformed. Further, the flight deck system will have access to increasing amounts of information and new and innovative means of communicating its desires to an ATM system; there will be more stringent performance requirements for avionics functions; and there will be a delegation of varying levels of responsibility to the flight deck for managing separation and generating/negotiating 4D trajectories relative to weather and other ATM constraints. Because of the complexity of NextGen, the degree of automation in the aircraft and in the ATM system will increase. Direct pilot/controller communications will be reduced and replaced by agent-based interactions between air and ground systems. Each of these new challenges is considered from a holistic flight deck system safety perspective by the Integrated Intelligent Flight Deck Technologies (IIFDT) project.

The purpose of this document is to identify those areas within the JPDO's conception of, and requirements for, NextGen that are being addressed, at least in part, through research being undertaken within the NASA's IIFDT project.

IIFDT Research Topics, Subtopics, and Milestones

In Table 1, the IIFDT research subtopics and milestones for the 2009 through 2013 fiscal years are summarized (IIFDT, 2009). As described in (IIFDT, 2009), research extends across four research levels, with higher numbered levels signifying increasing degrees of integration with

level 4 being complete flight deck systems. Research at the lower levels (e.g. Levels 1 and 2) rolls up and supports the research at the higher numbered levels (e.g. Levels 3 and 4).

This multi-level research framework is shown in (IIFDT, 2009) as a 'research pyramid' and is further decomposed into 10 research areas or topics: Flight Deck Systems (FDS), Robust Automation-Human Systems (RAHS), Displays and Decision Support (DDS), Operator Performance (OP), Enabling Avionics (EA), Design Tools (DT), Operator Characterization (OC), Sensing, Signal Processing, and Hazard Characterization (SS), Multi-Modal Interfaces (MM), and Information and Interaction Modeling (IM). In Table 1, research subtopics and milestones are summarized with respect to these topic identifiers. For more information on any of these topics, see (IIFDT, 2009).

Mapping JPDO-identified Needs to IIFDT research

To transition to NextGen, the JPDO has developed an Integrated Work Plan (JPDO, 2008) which includes five different integrated planning elements. Four of the five planning elements have direct relevance to research being conducted under IIFDT. These are Research activities (R), Development activities (D), Operational Improvements (OIs), and Enablers (EN). The fifth planning element, Policy, does not pertain to IIFDT research.

The JPDO defines 'Research Activities' as areas of basic or applied research needed to support or achieve other NextGen planned-for elements.   Closely related are 'Development Activities', which describe the results needed from ongoing development or demonstration programs to support other NextGen planned-for elements. 'Operational Improvements' describe specific realized operational changes deemed necessary under the NextGen Concept of Operations. Rather than describe operational changes after NextGen has been fully implemented, individual OIs describe performance improvements and changes in operations expected at a specific point in time, as the current air traffic management system transitions to the NextGen air traffic management system. Lastly, an 'Enabler' is a NextGen functional component that is deemed necessary, or must be in place, to support one or more OIs or other Enablers. Enablers include, for example, specific technologies or sensor capabilities, procedures, standards, communication, navigation, and surveillance systems and algorithms.

Table 2 cross-references the JPDO-defined research and development activities to related research being conducted or planned under IIFDT. Table 3 and Table 4 do the same with regard to the JPDO-defined operational improvements, and enablers, respectively.   An asterisk next to the identification number signifies that the JPDO has identified NASA as the Office with Primary Responsibility (OPR) or supporting OPR for accomplishing that research or development activity, operational improvement, or enabler. This indication does not mean that NASA's IIFDT project, in particular, has been assigned responsibility for the activity, however, just that NASA, as an agency, has been identified as the agency with primary responsibility to address the topic.

It is the intention of the IIFDT project to update these tables annually based on changes to NASA and/or JPDO plans, research findings, new technology developments, and emerging trends across the community.

References

(IIFDT, 2009) "Integrated Intelligent Flight Deck Technologies – Technical Plan Summary," NASA, www.aeronautics.nasa.gov/avsafe/iifd , March 13, 2009.

(JPDO, 2008) "NextGen Integrated Work Plan," JPDO, www.jpdo.org, September 30, 2008.

Table 1. Summary of IIFDT Research Topics, Subtopics, and Milestones (IIFDT, 2009)

Level 4 – Flight Deck Systems	
IIFD.FDS.1.1	Specification of NextGen-based flight deck system application domain, concept of operations and reference scenarios
IIFD.FDS.2.1	Assessment of flight deck system risk factors and barriers associated with enabling the NextGen-based application domain
IIFD.FDS.3.1	Establish flight deck system evaluation testbed
IIFD.FDS.3.2	Demonstrate advanced flight deck system solution concept
Level 3 – Robust Automation-Human Systems	
IIFD.RAHS.1.1	Hypothesized solution concept within specified application domain for flight deck system function allocation and human-automation interactions during 4-D trajectory-based operations
IIFD.RAHS.1.2	Evaluation of RAHS solution concept in relevant environment
Level 3 – Displays and Decision Support	
IIFD.DDS.1.1	Hypothesized solution concept within specified application domain for flight deck system displays and decision-support functions providing for better than visual operations, integrated alerting and notification, and collaborative environments
IIFD.DDS.1.2	Evaluation of DDS solution concept in relevant environment
Level 2 – Operator Performance	
IIFD.OP.1 (subtopic)	Methods for conveying and assessing situation awareness
IIFD.OP.2 (subtopic)	Methods for fostering appropriate use of automation and complex information sources
IIFD.OP.3 (subtopic)	Methods for supporting communication and collaboration among multiple intelligent agents
IIFD.OP.4 (subtopic)	Methods for supporting human decision-making; and reducing the propensity for, or consequences of, human error
Level 2 – Enabling Avionics	
IIFD.EA.1 (subtopic)	Information collection and management for reliability and integrity of service
IIFD.EA.1.1	Develop and verify an Integrated Alerting and Notification (IAN) system model suitable for design capture and evaluation against requirements
IIFD.EA.1.2	Develop and verify flight deck system information model to aid in understanding complex information redundancies and relationships
IIFD.EA.1.3	Evaluate IAN system model for determining context and hazard state

IIFD.EA.1.4	Demonstrate an executable Cockpit Information System Model (CISM) suitable for simulation-based trade studies of alternate information management function designs
IIFD.EA.1.5	Specify requirements for IAN information management
IIFD.EA.2 (subtopic)	Information processing for decision support
IIFD.EA.2.1	Evaluation of the IAN model with a Caution Warning Alert (CWA) function incorporated
IIFD.EA.2.2	Assessment of IAN functionality with respect to the meeting Level 3 human interface conceptual design requirements for information content, availability, timeliness, and integrity
Level 2 – Design Tools	
IIFD.DT.1 (subtopic)	Tools that support the design and evaluation of human-automation interaction
IIFD.DT.1.1	Develop and evaluate human-automation integration vulnerability prediction tools for NextGen flight deck technologies and concepts of operation
IIFD.DT.2 (subtopic)	Tools that support the design and evaluation of operations and environments that provide for coordinated situational awareness across multiple agents
IIFD.DT.2.1	Develop, verify, and validate model of coordinated multi-agent situation awareness
Level 1 – Operator Characterization	
IIFD.OC.1 (subtopic)	Identify the operationally-relevant characteristics of NextGen airspace operators
IIFD.OC.2 (subtopic)	Identify information requirements to support the roles of NextGen operators.
IIFD.OC.3 (subtopic)	Characterize the functional state of operators
Level 1 – Sensing, Signal Processing, and Hazard Characterization	
IIFD.SS.1 (subtopic)	Forward-looking remote sensing methods, models, and technologies
IIFD.SS.1.1	Complete initial investigation of forward-looking interferometric (FLI) sensing, including sensor results of ground testing, simulations, and characterization of sensor capabilities for detection of selected hazards
IIFD.SS.1.2	Complete feasibility studies of forward-looking interferometric (FLI) sensing including terminal area ground and flight testing to quantify performance prediction uncertainty and to provide data to advance the development of hazard detection capabilities
IIFD.SS.1.3	Evaluate the feasibility of Lidar sensor technology concepts for airborne wake vortex detection
IIFD.SS.1.4	Evaluate design of low-cost electronically-scanned radar antenna
IIFD.SS.1.5	Evaluate Near-Infrared (NIR) External Hazard Detection System

IIFD.SS.1.6	Develop and evaluate methods and systems to detect and track non-cooperative traffic using enhanced ADS-B technology
IIFD.SS.1.7	Develop a pulsed-lidar model to support the investigation of the detection capabilities of lidar for icing, wake vortex, and clear air turbulence hazards
IIFD.SS.1.8	Re-assess strategic plan and initiate follow-on sensor investigations based upon capability and performance predictions, models, and technology development, quantification of uncertainties. This milestone is a decision point with regard to follow-on work and based on results of the initial studies reported in IIFD.SS.1.1 to IIFD.SS.1.7 as well as Level 3 concept evaluations and identified needs.
IIFD.SS.2 (subtopic)	Image processing and feature extraction
IIFD.SS.2.1	Develop and evaluate methods for FLIR image fusion and image processing to support Level 2 and 3 requirements for terminal area hazard awareness
IIFD.SS.2.2	Complete comprehensive design of Spatial Vision Tree (SVT) – a generic pattern recognition engine
IIFD.SS.2.3	Develop and verify methods for runway detection and runway object detection for FLIR and color video imaging systems
IIFD.SS.2.4	Demonstration of real-time image enhancement and pattern recognition system during terminal area operations for FLIR and color video imaging systems
IIFD.SS.3 (subtopic)	External hazard characterization
IIFD.SS.3.1	Assessment of external hazard detection and intensity algorithms for hazards in the terminal area
IIFD.SS.4 (subtopic)	Icing Remote Sensing and Characterization
IIFD.SS.4.1	Pre-flight assessment of the Multi-Frequency Radar (MFR) for characterization of atmospheric icing conditions, including ground operation and comparison with NIRSS radar performance
IIFD.SS.4.2	Assessment o the feasibility and benefit of a scanning, narrow-beam radiometer for the detection and classification of icing hazards
IIFD.SS.4.3	Assess instrumentation performance and flight operation procedures for High Ice Water Content (HIWC) flight research
IIFD.SS.4.4	Measure and record cloud properties that lead to engine icing for the purposes of developing models or databases that can be used to replicate such conditions in controlled environments, and to predict effects of mitigation methods
IIFD.SS.4.5	Methods for detection, prediction, and avoidance of atmospheric conditions that are conducive to HIWC engine icing based on analysis and characterization/ modeling of the hazard environment
IIFD.SS.5 (subtopic)	Operator state sensing and signal processing
IIFD.SS.5.1	Determine critical needs and technical gaps for operator state sensing
IIFD.SS.5.2	Conduct operator state sensor investigation to attack key technical barriers identified in previous work (IIFD.SS.5.1)

Level 1 – Multi-Modal Interfaces	
IIFD.MM.1 (subtopic)	Develop and evaluate improved visual interface capabilities
IIFD.MM.2 (subtopic)	Develop and evaluate improved aural/speech interface capabilities
IIFD.MM.3 (subtopic)	Develop and evaluate novel and multi-modal interface capabilities
Level 1 – Information and Interaction Modeling	
IIFD.IM.1 (subtopic)	Theoretical approaches for presenting large volumes of data in limited display space
IIFD.IM.1.1	Development and validation of general theory and executable model for data extraction, integration, and abstraction against baseline practices and Level 3 application
IIFD.IM.2 (subtopic)	Predictive modeling of human interaction performance
IIFD.IM.2.1	Development and validation of integrated model of automation and operator performance defined for Level 3 conceptual designs
IIFD.IM.3 (subtopic)	Formal models of fault-tolerant systems that include human elements
IIFD.IM.3.1	Development and validation of representative fault, error, and communication analysis models for both human and automation system components

Table 2. JPDO-identified R&D activities related to IIFDT research

ID	Initial Completion Date	Title	Description	IIFD Milestone or Subtopic
R-0350*	2009	Applied Research on Air and Ground-based Runway Incursion Detection Technologies	Applied research on complementary air- and ground-based runway incursion prevention and detection systems.	DDS.1.1 DDS.1.2 EA.1 EA.2 DT.2 SS.1 SS.2 SS.3 MM.2
R-0370*	2009	Applied Research on Traffic Spacing Management in Terminal and Transition Airspace	Research on traffic spacing management (e.g., complementary time-based metering, management by 4DT, and sequence-based pair-wise spacing) for transition, arrival, and departure operations to support alternative selection and policy decisions on high-throughput delivery of aircraft to the runway threshold and high-throughput departure operations.	RAHS,1.1 RAHS.1.2
R-0530*	2009	Applied Research on Automated Air and Ground Separation Management Alternatives	Research on ground and aircraft automated separation management options (e.g., fully automated ground-based separation management, automation-assisted aircraft-based or ground-based separation management, and performance-based combinations)	RAHS,1.1 RAHS.1.2
R-0590	2009	Applied Research on Optimizing Visual Flight Rule (VFR) Operations	Research on operational concepts for reducing visibility and cloud clearance requirements for VFR flight for alternative selection of increased utility of VFR operations	DDS.1.1 DDS.1.2 SS.1 SS.2

R-0610*	2009	Applied Research on Safe Taxi Operations in Low Visibility Conditions	Research on safe taxi operations in zero/zero visibility conditions to support an alternative selection on appropriate operator/ANSP roles in zero visibility operations.	DDS.1.1 DDS.1.2 DT.2 EA.1, EA.2 SS.1, SS.2, SS.3 MM.1
R-0930*	2009	Applied Research on Low Visibility Independent Parallel and Converging Approach Procedures	Complete applied research on cockpit technologies and procedures to support an alternative selection for independent parallel and converging runway procedures in low visibility.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2, SS.3 DT.2 MM.1
R-1240*	2009	Applied Research on Low Visibility Dependent Multiple Approach Procedures	Complete applied research on technologies and procedures to support an alternative selection for very closely spaced parallel runway procedures in low visibility.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2, SS.3 DT.2 MM.1
R-1430*	2009	Applied Research on Human/ Automation Roles in High-Density Surface Operations	Research on alternative aircraft/ground and human/automation roles and responsibilities to support an alternative selection for taxi instruction information and procedures enabling effective high-density surface operations.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 OP.1, OP.2 OP.3, OP.4 DT.1, DT.2

R-1440*	2009	Applied Research on Complex Systems Validation and Verification	Research and development of methods for verification and validation of complex systems to support alternative NextGen risk assessment and certification decisions.	FDS.2.1 FDS.3.2 DT.1, DT.2 IM.3
D-0330*	2009	Aircraft-Based Precision Approach Capability	Develop aircraft-based precision approach capability to support an implementation decision for aircraft-based approach and landing with performance approach capability to support approach and landing with performance similar to category (CAT) II/III ground-based landing guidance systems.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2, SS.3
D-0360*	2009	Requirements for Taxi Instructions Submission	Develop digital transmission and onboard display of taxi instructions to support an implementation decision on low-visibility taxi guidance.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 OP.3 DT.2
D-0830	2009	Trajectory Negotiation Protocols for Air and Ground Information Architectures	Develop protocols to negotiate TBO trajectories to support an implementation decision on the aircraft and ground information architectures.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2
D-0880	2009	Terminal and Surface Low Visibility ConOps	Develop low visibility operations to support implementation decisions for terminal and surface operations.	DDS.1.1 DDS.1.2 DT.2 SS.1, SS.2, SS.3 MM.1
D-1200	2009	Guidance for Trajectory-Based Procedures	Develop trajectory-based ATC procedures to support a national policy decision on liabilities related to changes in roles and responsibilities among automation and humans, and among air traffic service providers and flight operators	RAHS.1.1 RAHS.1.2 OP.1, OP.2 OP.3, OP.4 DT.1, DT.2

D-1250	2009	Safe Taxi Operations in Low Visibility Conditions	Develop aircraft and ground vehicle movement on airport surface in zero/zero visibility conditions to support an implementation decision.	DDS.1.1 DDS.1.2 DT.2 EA.1, EA.2 SS.1, SS.2, SS.3 MM.1
D-1680	2009	Advanced Wake Sensing Capabilities	Research on safety nets (such as wake sensing) to support an alternatives decision on the for dynamic wake spacing	SS.1, SS.2, SS.3
D-1700	2009	System Risk Assessment and Management Models	Complete development of system risk assessment and management models to applied research on the allocation of capabilities across flight operator and ANSP automation.	FDS.2.1 FDS.3.2 DT.1, DT.2 IM.1, IM.3
R-2130*	2010	Applied Research on Risk-Reducing Systems Interfaces, Procedures, and Training	Applied research on risk-reducing systems interfaces, procedures, and training to reduce human error for the range of NextGen stakeholders.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.1, OP.2 OP.3, OP.4 EA.1, EA.2 DT.1, DT.2 OC.1,OC.2,OC.3 SS.5 MM.1, MM.2 MM.3
R-2138	2010	Applied Research on Human Error Using Automated Systems	Applied research on human-system performance models that will accurately capture human variability and error using NextGen automated systems.	RAHS.1.1 RAHS.1.2 OP.2,OP.3,OP.4 DT.1, DT.2 OC.1 IM.2

D-2100	2010	Complex System Validation and Verification Tools and Techniques	Complete development of methods for verification and validation of complex systems to support alternative NextGen risk assessment and certification decisions.	FDS.2.1 FDS.3.2 EA.1, EA.2 DT.1, DT.2 IM.3
R-0500*	2011	Applied Research on Variable Separation Standards	Research on options for procedures, standards specification, decision-support aids, and displays to support an alternative selection to enable variable separation standards based on performance levels	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.2, OP.4 EA.1, EA.2 OC.2 SS.1 IM.1
R-0960	2011	Applied Research on 4D Trajectory Evaluation, Planning, Presentation, and Negotiation	Research on operator and ANSP capabilities for 4D aircraft-trajectory evaluation, planning, presentation, and negotiation to support alternative selection and policy for 4D flight-planning and collaborative air traffic management.	DDS.1.1 DDS.1.2 RAHS.1.1 RAHS.1.2 OP.3 OC.1
D-2133*	2011	Air and Ground-Based Runway Incursion Detection Technology	Development of complementary air- and ground-based runway incursion prevention and detection systems.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1,SS.2,SS.3

				RAHS.1.1
D-1710*	2012	Risk Reducing Interfaces, Procedures, and Training	Complete applied research on risk-reducing systems interfaces, procedures, and training to reduce human error and complement the development of automation procedures for the range of NextGen stakeholders.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.1, OP.2 OP.3, OP.4 EA.1, EA.2 DT.1, DT.2 OC.1,OC.2,OC.3 SS.5
R-0140	2013	Applied Research on 4DT use in Clearances and Flight Plans	Research on the initial use of and exchange of four-dimensional trajectory information in clearances and flight plans to support an alternatives selection decision for further development and incorporation into future flight planning systems, air traffic management automation, and aircraft flight management systems.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 DT.2
R-0820*	2013	Applied Research for Required Aircraft 4DT Intent Data	Research on 4DT intent data outputs and associated precision requirements for fixed and variable separation procedures (including aircraft- and ground-based operations) to support implementation decisions on TBO in performance-based airspace.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.3 EA.2 DT.2
R-1260*	2013	Applied Research on Risk-reducing Systems Interfaces, Procedures, and Training	Research on risk reducing systems interfaces for reducing human error to support alternative NextGen equipage decisions.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.1, OP.2 OP.3, OP.4 EA.1, EA.2 DT.1, DT.2 OC.1,OC.2,OC.3 SS.5

R-2121	2013	Applied Research on Human Performance Models	Applied research to support human performance models that accurately capture human variability and human error in highly automated NextGen systems.	RAHS.1.1 RAHS.1.2 OP.2,OP.3,OP.4 DT.1, DT.2 OC.1 IM.2
D-2155	2013	Availability and Accessibility of Required Information Design Guidelines	Development of design guidelines for various system interfaces that reduce manipulation required to access needed information. Interfaces will address shortcomings where the information is available, but the number of steps required to obtain the information is problematic. These guidelines will be developed for airborne and ground-based systems. The research and development supporting the development of these guidelines will also identify the interfaces for this continuous safety improvement enabler.	DDS.1.1 DDS.1.2 OP.2 EA.1, EA.2 MM.1, MM.2 MM.3 IM.1
D-2157	2013	Usefulness and Understandability of Information Design Guidelines	Development of design guidelines for various system interfaces that target the reduction of human error due to confusion concerning information presented. These guidelines will be developed for airborne and ground-based systems. The research and development supporting the development of these guidelines will also identify the interfaces for this continuous safety improvement enabler.	DDS.1.1 DDS.1.2 OP.1, OP.2 EA.1, EA.2 MM.1, MM.2 MM.3 IM.1

D-2159	2013	Appropriate Human Engagement Design Guidelines	Development of design guidelines for various system interfaces that target the reduction of human error due to automation mode confusion and user complacency due to over reliance on automation. Interfaces based on these guidelines will reduce the risk of the human not understanding what the automation is doing and how it is performing and address the issue of the appropriate roles of the human and automation in a systems context. These guidelines will be developed for airborne and ground-based systems. The research and development supporting the development of these guidelines will also identify the interfaces for this continuous safety improvement enabler.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.1, OP.2 OP.3, OP.4 DT.1, DT.2 OC.1, OC.2 MM.1, MM.2 MM.3
D-2161	2013	Operational Decision Aids Design Guidelines	Development of design guidelines for technologies that reduce time required to optimize decisions, reduce the number of hazards encountered, and mitigate consequences of hazard encounter. These airborne technologies will improve the awareness and mitigate response to airborne events and hazards. These technologies will reduce the time required to optimize decisions and reduce the number of hazards actually encountered. The research and development supporting the development of these guidelines will also identify the system for this continuous safety improvement enabler.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.2, OP.4 EA.1, EA.2 OC.2 SS.1, SS.2 SS.3,SS.4,SS.5
D-2163	2013	Reliability and Airworthiness of Aircraft Design Guidelines	Development of design guidelines for various technologies that reduce system-level failures and reduce diversions or non-complete missions. Technologies based on these guidelines will bring greater reliability to aircraft systems, including controls, avionics, and data and information management, as well as, the long-term structural airworthiness of new materials and advanced aircraft designs. The research and development supporting the development of these guidelines will also identify the systems for this continuous safety improvement enabler.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2 SS.3, SS.4 IM.3

D-2167	2013	Reliability and Accuracy of Data and Information Design Guidelines	Development of design guidelines for technologies that increases the reliability and accuracy of the data received by the aircraft and reduces the amount of processing required to understand said data and information. The research and development supporting the development of these guidelines will also identify the systems for this continuous safety improvement enabler.	EA.1, EA.2 OC.2 SS.1, SS.2 SS.3, SS.4 IM.1
R-1120*	2014	Applied Research on Automated Flight and Flow Evaluation and Resolution Capabilities	Research on collaborative automated flight and flow evaluation and resolution capabilities to support an alternative selection on how flight operators and ANSP negotiate objectives and trajectory preferences to balance priorities, including roles and responsibilities.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.3 DT.2
R-1150*	2014	Applied Research on Airframe and Aircraft System Weather Mitigation Technique Benefits	Research on airframe and aircraft system weather mitigation techniques and their respective operational benefits to support an implementation decision based on the advisability of NextGen airborne weather mitigation under various routine and hazardous weather conditions.	EA.1, EA.2 SS.1, SS.2 SS.3
R-0640*	2016	Applied Research on Metroplex Throughput Optimization	Research on performance based trajectories through transition airspace to support an alternative selection to maximize metroplex throughput.	RAHS.1.1 RAHS.1.2
R-1600	2018	Applied Research on Aircraft-Based CNS Technologies in Self-Separation Airspace	Research on aircraft-based CNS performance levels to develop requirements for self-separation operations.	RAHS.1.1 RAHS.1.2 EA.1, EA.2 SS.1

* NASA is the identified Office with Primary Responsibility (OPR) or Supporting OPR for this Research and Development Activity

Table 3. JPDO-identified Operational Improvements related to IIFDT research

ID	Date	Title	Description	IIFDT Milestone or Subtopic
OI-0311*	2010	Enhance Arrival/Departure Routing and Access	Performance-based navigation operations are used on terminal area arrival and departure routes to increase utilization of high-density terminal area airspace and to provide greater access to terrain-challenged airports and airports without expensive ground infrastructure in Instrument Meteorological Conditions (IMC). Less noisy and more fuel-optimal routes, including CDAs, are used where and when feasible and environmental constraints are met through routing decisions and dispersion of traffic over multiple RNP routes. Opens more options for airport access in various meteorological conditions.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2
OI-0316*	2012	Enhanced Visual Separation for Successive Approaches	This OI increases runway throughput in low ceiling and visibility conditions by allowing an aircraft to augment out-the-window visual separation information with onboard traffic display information on a visual approach. After establishing initial visual contact, the aircraft can continue a visual approach while traversing a light cloud layer, using the onboard traffic display briefly to augment situational awareness until visual contact is reestablished. This OI enables Visual Meteorological Condition (VMC) runway capacity levels to be achieved in marginal VMC for single, parallel and converging runways.	DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2
OI-0321	2014	Surface Management - Level 2 Datalink/ Departures	Efficiency of surface traffic movement is increased through the use of automation, and data link of departure taxi instructions prior to pushback to properly equipped aircraft to reduce delay, environmental impacts and operational errors. Automation optimizes surface throughput and data links taxi instructions to aircraft. The taxi instructions include the Two-Dimensional (2D) route. Waterfall deployment: a) some airports (Segment 2) b) OEP airports (Segment 3) c) top 100 airports (Segment 4) d) all commercial airports (Segment 6).	DDS.1.1 DDS.1.2 DT.2 EA.1, EA.2

OI-0326*	2014	Airborne Merging and Spacing - Single Runway	Arriving or departing aircraft to/from single runways are instructed to achieve and maintain a given spacing in time or distance from a designated lead aircraft as defined by an ANSP clearance. Onboard displays and automation support the aircraft conducting the merging and spacing procedure to enable accurate adherence to the required spacing. Flight crews are responsible for maintaining safe and efficient spacing from the lead aircraft. Responsibility for separation from all other aircraft remains with the ANSP. Assigned spacing may include a gap to allow for an intervening departure between subsequent arrivals. Mixed-equipage operations are supported; a spacing-capable aircraft can perform airborne spacing behind a non-capable aircraft as long as it is transmitting cooperative surveillance information. This OI includes multiple streams merging to a single runway and includes development of ANSP capability and procedures.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 OP.2, OP.3 DT.1, DT.2 OC.2 SS.1
OI-0332*	2016	Ground-based and On-board Runway Incursion Alerting.	This OI increases the safety of operations by reducing runway incursions. ANSP personnel managing approach and surface traffic receive runway incursion alerts from ground-based incursion detection systems and from aircraft equipped with onboard incursion detection systems. Operators of suitably equipped commercial, business, and general aviation aircraft receive runway incursion alerts from on-board detection systems and from complementary ground-based detection systems where implemented. Airborne equipage is optional. This OI will require research and development of runway incursion alerting systems appropriate for business, general aviation, and commercial aircraft, as well as complementary air- and ground-based functionality.	DDS.1.1 DDS.1.2 OP.2, OP.4 EA.1, EA.2 SS.1,SS.2,SS.3 MM.1, MM.2 MM.3 IM.1
OI-0333*	2016	Airborne Merging and Spacing for Multiple Runways	Arriving or departing aircraft to/from multiple runways are instructed to achieve and maintain a given spacing in time or distance from a designated lead aircraft as defined by an ANSP clearance. Onboard displays and automation support the aircraft conducting the merging and spacing procedure to enable accurate adherence to the required spacing. Flight crews are responsible for	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 OP.1,OP.2,OP.3

				maintaining safe and efficient spacing from the lead aircraft. Responsibility for separation from all other aircraft remains with the ANSP. Assigned spacing may include a gap to allow for an intervening departure between subsequent arrivals. Mixed-equipage operations are supported; a spacing-capable aircraft can perform airborne spacing behind a non-capable aircraft as long as it is transmitting cooperative surveillance information. This OI includes complex merging and spacing, such as for crossing and diverging streams and includes development of ANSP capability and procedures. Because an aircraft is spacing from its lead aircraft according to whatever spacing timing he is assigned by the ANSP, dynamic spacing with specific pair-wise spacing requirements are supported.	DT.1, DT.2 OC.2
OI-0322*	2017	Low-Visibility Surface Operations		Aircraft and ground vehicle movement on airports in low visibility conditions is guided by moving map displays, Cockpit Display of Traffic Information (CDTI), Automatic Dependent Surveillance-Broadcast (ADS-B) (for flight vehicles), and a Ground Support Equipment (GSE) Cooperative Surveillance System (for ground support equipment). Safety and efficiency of operations at some airports will also be enhanced by intelligent signage on the ground. Policy issue: Will this equipage be mandatory for access to some high-density airports during peak traffic times in low-visibility conditions, or will the equipped aircraft be given priority access in low-visibility, but unequipped aircraft will be accommodated, or is this equipage simply optional. Research issue/policy question: responsibility for all aspects of separation for operator vs. Air Navigation Service Provider (ANSP) and humans vs. automation.	DDS.1.1 DDS.1.2 EA.1, EA.2 OP.2 DT.2 MM.1 SS.1, SS.2
OI-0334*	2017	Independent Parallel or Converging Approaches in IMC		This OI enables maintaining Visual Meteorological Condition (VMC) arrival and departure rates in IMC through use of onboard displays and alerting for independent parallel or converging runways. Using precision navigation, cooperative surveillance, and onboard algorithms and displays allows the reduction of lateral separation requirements for converging and parallel runway	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2

			operations in IMC. Includes independent approaches to converging and parallel runways that are 4300 - 2500 ft centerline distances. The timing of implementation of this OI is strongly dependent on when an airline decides this is important and steps forward to advocate for it. Waterfall deployment: a) At selected locations b) All applicable OEP airports (2018+).	
OI-0306	2018	Provide Interactive Flight Planning from Anywhere	Flight planning activities are accomplished from the flight deck as readily as any location. Airborne and ground automation provide the capability to exchange flight planning information and negotiate flight trajectory contract amendments in near real-time. The key change is that the Air Navigation Service Provider's (ANSP) automation allows the user to enter the flight plan incrementally with feedback on conditions for each segment. Rather than testing full trajectories by submitting and waiting for full routes evaluations, the system will test each segment as entered and provide feedback. Through this process the user will work with the system to quickly reach a flight plan agreement. As before any subsequent change, constraint, preference, or intent triggers a full flight plan review with feedback to the filer. The filer can develop preferred trajectories that may include an identified constraint that the automation system maintains in case subsequent changes to conditions will allow its promotion to agreement. Automation thus maintains multiple flight plans for an individual flight.	RAHS.1.1 RAHS.1.2 EA.1, EA.2
OI-0327*	2018	Surface Management - Level 3 Arrivals/Winter Ops/Runway Configuration	This OI increases efficiency and safety of surface traffic movement, with corresponding reduction in environmental impacts. Efficiency of surface movement is increased through the use of automation, on-board displays and data link of taxi instructions on arrival to properly equipped aircraft to reduce delay and environmental impacts and improve safety. This OI assumes development of surface automation that is fully integrated with airborne operations and applies this to surface management operations. This OI is an extension of OI 321 and contains those improvements as well. Surface optimization automation includes activities such as runway	DDS.1.1 DDS.1.2 EA.1, EA.2 DT.2

			snow removal, aircraft de-icing, and runway reconfiguration. Waterfall deployment: a) OEP airports (Segment 5) b) top 100 airports (Segment 6) c) all commercial airports (Segment 7).	
OI-0358*	2018	Trajectory-Based Mgmt - Level 2 Trajectory Mgmt. Decision Support	All in-flight aircraft operating in Trajectory-Based Airspace are managed by 4DT in En Route climb, cruise, and descent. This may be considered a staging of the 4DT-based capability. This would require the ability to calculate, negotiate, and perform conformance monitoring by ANSPs, including the integration of separation assurance and traffic management (time constraints, e.g., RTAs). This will be enabled by the trajectory exchange through electronic data communications. In high-density or high-complexity airspace, precise 4DTs will be used, dramatically reducing the uncertainty of an aircraft's future flight path, in terms of predicted spatial position (latitude, longitude, and altitude) and times along points in its path. This enhances the capacity and throughput of the airspace to accommodate high levels of demand.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 DT.2
OI-0317*	2020	Near Zero Ceiling/Visibility Airport Access	Near Zero Ceiling/Visibility Airport Access is available where needed through a combination of complementary airborne and ground functionality to aid the pilot in approach guidance and acquisition of the runway environment for safe operations. Near zero ceiling/visibility (CAT-IIIc) approaches are available for all suitably-equipped users through a combination of complementary airborne and ground equipage. Implementation may involve on-board synthetic and enhanced vision systems, and Ground-Based Augmentation Systems (GBAS), and low-cost runway/taxiway lighting.	DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2, SS.3 MM.1
OI-0341*	2020	Limited Simultaneous Runway Occupancy	Runway capacity is increased through the allowance of multiple aircraft on the runway for specific situations. Expected use: One aircraft can land while another one is exiting to a taxiway, one aircraft can enter the runway while another aircraft is departing. This operation is routinely used by the military to enable expeditious movement of traffic but does require close cooperation and knowledge of the pilots involved with the operation. One way	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 DT.2 SS.1, SS.2

			to enable this operation is by the use and transmission of precision surveillance, very accurate prediction and adherence to 4DT (air and ground) and easily accomplished escape procedures. This Operational Improvement requires a Policy Decision. This is highly controversial, but would be transformational and depending on how it is implemented could have a significant impact on runway capacity.	
OI-0360*	2020	Trajectory-Based Mgmt - Level 3 Automation-Assisted Trajectory Negotiation	Trajectory management is enhanced by automated assistance to negotiate with properly equipped aircraft operators. Human ANSPs are responsible for separation management, supported by automation. 4DTs are negotiated between the ground-based automation and the operator, which may be the pilot, a Unmanned Aircraft System (UAS) operator, or perhaps even FOC personnel, who would then relay information to the aircraft. This will enable higher density of operations thus higher capacity as well as decrease human errors in trajectory negotiation and entry.	RAHS.1.1 RAHS.1.2 DT.1, DT.2 EA.1, EA.2
OI-0339*	2022	Integrated Arrival/Departure and Surface Traffic Management for Metroplex	Metroplex traffic flow is more effectively managed through terminal area and surface scheduling automation for increased regional capacity. Metroplex planners at major terminal areas optimize arrival/departure and surface scheduling for increased regional capacity. Trajectory-based operations is a key element of super-density procedures, allowing the ANSP to maximize access for all traffic, while adhering to the principle of giving advantage to those aircraft with advanced capabilities that support the air traffic management system. Metroplex trajectory management assigns each arriving aircraft to an appropriate runway, arrival stream, and place in sequence.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2
OI-0362*	2022	Self-Separation - Self-Separation Airspace	In self-separation airspace, capable aircraft are responsible for separating themselves from one another, and the ANSP provides no separation services, enabling preferred operator routing with increased ANSP productivity. Research will determine whether the ANSP will provide any traffic flow management services within self-separation airspace. Aircraft must meet equipage requirements	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2

			to enter self-separation airspace, including transmission of trajectory intent information through cooperative surveillance. Transition into self-separation airspace includes an explicit hand-off and acceptance of separation responsibility by the aircraft. Transition into ANSP-managed airspace is facilitated through assigned waypoints with Controlled Time of Arrivals (CTAs), allowing the ANSP to sequence and schedule entry into congested airspace, and self-separating aircraft are responsible for meeting assigned CTAs. Self-separating aircraft execute standardized algorithms to detect and provide resolutions to conflicts. Right-of-way rules determine which aircraft should maneuver to maintain separation when a conflict is predicted. Contingency procedures ensure safe separation in the event of failures and operational errors.	
OI-0369	2024	Trajectory-Based Mgmt - Level 4 Automated Negotiation/ Separation Mgmt	Trajectory management is enhanced by automated negotiation of 4DTs between properly equipped aircraft and ground automation for separation management. All aircraft in TBO airspace must be equipped for this function. The ANSP Separation Management function is fully automated, and separation responsibility is delegated to automation. For specified operations, tasks are delegated to the flight crew to take advantage of aircraft capabilities. To manage separation, ANSP automation negotiates short-term, conflict-driven updates to the 4DT agreements with the aircraft. This will enable higher density of operations thus higher capacity as well as a decrease in human errors in trajectory negotiation and entry. This Operational Improvement requires a Policy/Implementation Decision to determine appropriate roles/responsibilities allocated between humans/automation and air/ground.	RAHS.1.1 RAHS.1.2 EA.1, EA.2 OP.2 DT.1, DT.2
OI-0340*	2025	Near-Zero-Visibility Surface Operations	Aircraft and ground vehicle movement on airports in near-zero/zero visibility conditions is guided by technology such as moving map displays, Cockpit Display of Traffic Information (CDTI), enhanced vision sensors, synthetic vision systems, ADS-B (flight vehicles), and a Ground Support Equipment (GSE) Cooperative Surveillance	DDS.1.1 DDS.1.2 DT.2 EA.1, EA.2 SS.1,SS.2,SS.3

			System (CSS) (for ground vehicles). Requires all present aircraft and ground vehicles to have cooperative surveillance (ADS-B out). Cost/benefit analysis will determine visibility goal to support. Research issue/policy question: responsibility for all aspects of separation for operator vs. ANSP and humans vs. automation.	MM.1
OI-0348	2025	Reduce Separation - High Density Terminal, Less than 3-mile	Metroplex airspace capacity is increased through implementing separation standards of less than 3 nm between high navigation precision arrival and departure routes. This Operational Improvement increases metroplex airspace capacity and supports super density airport operations by implementing separation standards for inter-aircraft separations of less than 3 nm. Arrival/departure routes with lower RNP values (e.g., RNP<1 nm) are defined with less than 3 miles lateral separation between routes, subject to wake vortex constraints, enabling the use of more routes in a given airspace. This may require airborne lateral separation between routes. Enhanced RSP is required. This requires a Policy Decision to determine what RNP values to require based on performance benefit versus equipage requirements and operational considerations. Expected use: high density terminal and transition airspace.	RAHS.1.1 RAHS.1.2 EA.1, EA.2 SS.1, SS.2
OI-0363*	2025	Delegated Separation - Complex Procedures	In ANSP-managed airspace, the ANSP delegates separation responsibilities to capable aircraft to improve operator routing, enhance operational efficiency, or increase ANSP productivity. This Operational Improvement involves more complex delegated separation responsibilities that may be supported in ANSP-managed En Route and transition airspace. After early concept exploration and feasibility research, an implementation decision will be made by 2015 to determine whether it is cost beneficial to develop additional delegated separation responsibilities beyond those covered in OI-0356 taking advantage of advanced airborne technologies, such as conflict detection and alerting.	RAHS.1.1 RAHS.1.2 EA.1, EA.2 SS.1, SS.2

OI-0370	2025	Trajectory-Based Management - Level 5 Full Gate-to-Gate	All aircraft operating in high density airspace are managed by 4DT in En Route climb, cruise, descent, and airport surface phases of the flight. This is the end state 4DT-based capability. This would require the ability to calculate, negotiate, and perform conformance monitoring by ANSPs including the integration of separation assurance and traffic management time constraints (e.g., runway times of arrival, gate times of arrival). This will be enabled by the trajectory exchange through electronic data communications, as well as many new surface automation and 3D (x, y, and time) trajectory operations. In high-density or high-complexity airspace, precise 4DTs will be used, dramatically reducing the uncertainty of an aircraft's future flight path, in terms of predicted spatial position (latitude, longitude, and altitude) and times along points in its path. This enhances the capacity and throughput of the airspace to accommodate high levels of demand. In trajectory-based airspace, differing types of operations are conducted with performance-based services applied based on the anticipated traffic characteristics. User preferences are accommodated to the greatest extent possible, and trajectories are constrained only to the extent required to accommodate demand or other national concerns, such as security or safety.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 DT.1, DT.2
OI-3103	2025	Improved Safety of Operational Decision Making	Systems interfaces that reduce the risk of error in operational decision making are essential to maintaining and improving aviation safety. Systems interfaces are improved to provide better situation awareness. System designs are improved to maintain appropriate human engagement, and improved operational decision aids are implemented to support task completion in nominal and off-nominal system states.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.1, OP.2 OP.3, OP.4 EA.1, EA.2 DT.1, DT.2 SS.5 MM.1, MM.2 MM.3 IM.1, IM.2

| OI-3104 | 2025 | Enhanced Safety of Airborne Systems | Safety requirements are integrated into the development and implementation of NextGen advancements for aircraft, to maintain or improve safety as changes are introduced. The reliability and airworthiness of aircraft is improved at the sub-system level; vehicle systems health management is improved at the sub-system and system level. The reliability and accuracy of operational information sourced from vehicle systems is improved. Aircraft conformance to more stringent operational requirements is improved, and aircraft system contributions to crash survivability are enhanced. | EA.1, EA.2 SS.1, SS.2, SS.5 |

* NASA is the identified Office with Primary Responsibility (OPR) or Supporting OPR for this Operational Improvement

Table 4. JPDO-identified Enablers related to IIFDT research

ID	Initial Availability	Title	Description	IIFDT Milestone or Subtopic
EN-0028	2011	Avionics - Access to Airspace Boundary Information	Aircraft operator has real-time onboard access to information on boundaries and performance requirements for airspace, including arrival, departure, and other high-density route structures, SUAs, flow corridors, and self-separation airspace.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 IM.1
EN-0102	2011	Avionics - Moving Map Display	Electronic map and display of airport ramps, taxiways, and runways showing real-time own-ship position, and cooperating surface traffic and ground vehicles.	DDS.1.1 DDS.1.2 EA.1, EA.2 DT.2
EN-0200	2011	Avionics - Traffic Display Level 2	Display/Device that allow an aircraft to augment out-the-window visual separation information with onboard traffic information on a visual approach. This will also allow multiple aircraft on the runway simultaneously for specific operations.	DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2
EN-2680	2011	Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 1	This enabler provides guidance, methodologies, and algorithms for weather assimilation into decision-making. This is accomplished through initial, crosscutting, foundational research such as: translation of weather's impact on operations, operational metrics development, determination of NextGen relevant weather information, basic mathematical research into optimization methodologies, operational research analysis, techniques for the presentation of probabilistic information to humans and automation, characterization of hazardous weather phenomena (e.g., estimation of aircraft-specific weather hazard levels, pilot likelihood to deviate, permeability of weather), and benefits pool estimation. This near-term research will likely produce more immediately useable	DDS.1.1 DDS.1.2 EA.1, EA.2 OP.4 OC.2 SS.1, SS.2 SS.3, SS.4 IM.1

			results for weather assimilation for the en route and terminal domains, because of the current maturity of research in en route weather conflict prediction and resolution; arrival/departure separation standards due to wake vortex turbulence; and ceiling and visibility impacts on airport arrival rates. Another reason these capabilities are anticipated in the near-term is that the look-ahead time for the required weather is relatively short, resulting in levels of weather uncertainty that can be more easily addressed. Some early, less sophisticated results in the assimilation of weather in the Traffic Flow Management (TFM) domain and surface operations may also be achieved.	
EN-3119	2011	Integrated Safety Assurance and Risk Management - Level 1	This enabler will reduce the risk of accidents and incidents through enhanced analysis of safety data/information in the Air Transportation System (ATS). Safety analysis is enhanced through the collection and sharing of safety data across the Air Transportation System (ATS) and the consistent application of safety assurance and prognostic methods of identifying and assessing risks. This enabler begins the transformation from reactive safety management to a more integrated proactive approach that requires advancing the methods used to identify and mitigate latent and emergent safety risk in the ATS. Vulnerabilities, hazards, threats, etc. are sought, identified, and managed before they result in an incident or accident. An integrated risk management capability is developed to evaluate the performance of individual capabilities (existing or planned) in the context of their net impact on risk (safety assessments) and the interdependencies of related capabilities and their impact on overall system risk. An integrated analysis promotes the capability to support a National Safety Management System, per OI 3004. Level 1 stakeholders include National Aeronautics and Space Administration	FDS.2.1 DT.1, DT.2 IM.3

			(NASA), Federal Aviation Administration (FAA), and where appropriate, industry partners. Level 1 leverages and integrates existing architectures, systems, data sources, tools, policies and procedures. The success of this enabler is dependent on a trusted safety information sharing environment, based on elements of a positive safety culture (e.g., informed culture, reporting culture). Government/industry safety information sharing agreements are formalized.	
EN-1007*	2012	Avionics - Trajectory Management - Advanced Surface Operations	A device/display that will assist aircraft in surface coordination and execution of surface management using precision navigation, cooperative surveillance, and onboard algorithms and displays that enable surface movement and guidance control.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2 DT.2
EN-0031*	2013	Avionics - Airborne Merging and Spacing	Development, validation, and implementation of aircraft technologies and procedures for airborne merging and spacing capability to meet requirements for all NextGen en route and terminal area merging and spacing applications (single-runway, complex and metroplex terminal area ops, dynamic spacing assigned by ground automation, en route merging and spacing in constrained environments, and flow corridor entry, exit, station-keeping and passing operations).	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2
EN-0005	2014	4D Flight Plan Automation - Operator	Flight operators have means to file flight plans as requested Four Dimensional Trajectory (4DT) through Flight Operation Centers (FOCs) or private services.	RAHS.1.1 RAHS.1.2
EN-0106*	2014	Avionics - Delegated Separation - Maneuver Guidance Information	Device/Display enabling separation operations, to include both a single aircraft having separation authority for a specific maneuver (e.g., for crossing or passing another aircraft) or more general separation responsibility, such as for flow corridors. This will allow ANSP and aircraft automation to track the delegation of responsibility and its limits and ensure that the delegation is always unambiguous	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2

			and clearly communicated.	
EN-3108	2014	Enhanced Focus on Safe Operational Procedures	NextGen concepts will be realized through the execution of new and improved operational procedures. Updated procedures will be required to support new ground-based and airborne systems in the areas of communication, navigation, surveillance, air traffic management, vehicle systems, manufacturing methods, systems health management, and maintenance. The safety of these operational procedures must be assured at multiple levels beginning with an examination of the overall structure of NextGen and its concepts. As NextGen operational improvements are refined and their enabling technologies are developed, continued focus on their safety implications must be maintained and safety requirements must be integrated into the development of operational procedures associated with them. Rapidly evolving human roles and responsibilities, as well as human-centered interfaces, will be associated with technological advances. The procedures developed to make use of these advances must focus on effective information management and use of decision aids, enhanced communication, and situation awareness.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.1, OP.2 OP.3, OP.4 EA.1, EA.2 DT.1, DT.2 OC.2 MM.1, MM.2 MM.3 IM.1, IM.2, IM.3
EN-0103*	2015	Avionics - Trajectory Management - Arrival/Departure	A device/display that will assist aircraft in the coordination and execution of Trajectory Management using precision navigation, cooperative surveillance, and onboard algorithms and displays that allows the reduction of lateral separation requirements.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 EA.1, EA.2
EN-3058	2015	Increased Reliability and Accuracy of Data and Information - Level 1	As design guidelines are developed (continuous), implement and deploy technologies that reduce data acquisition, processing and display errors. These technologies will increase the reliability and accuracy of data/information, with a performance measure of reduced data acquisition, processing, and display errors. (Level 1 - less difficult improvements, component level)	EA.1, EA.2 SS.1, SS.2

EN-3060	2015	Improved Operational Decision Aids - Airborne Level 1	As design guidelines are developed (continuous), implement and deploy technologies that reduce time required to optimize decisions and reduce the number of hazards encountered. These technologies will improve the awareness and mitigate response to airborne events and hazards. The performance measures are reduced time required to optimize decisions and a reduced number of hazards actually encountered. (Level 1 - less difficult improvements, component level)	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.4 EA.1, EA.2 OC.2 SS.1, SS.2, SS.3 SS.4, SS.5 IM.1
EN-3110	2015	Ensure the Availability and Accessibility of Required Information	Provide and assure the continuity of critical information and limit the manipulation required for operator access.	EA.1, EA.2
EN-3111	2015	Increase the Usefulness and Understandability of Information	System interfaces that target the reduction of human error due to misunderstanding of system information. Greater usefulness and understandability of information will improve situation awareness. This applies equally to airborne and ground-based systems.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.1, OP.2 OP.3, OP.4 DT.1, DT.2 OC.2 MM.1, MM.2 MM.3 IM.1
EN-3112	2015	Maintain Appropriate Human Engagement	To meet demands for capacity and safety, the current trend toward automated systems with increased capabilities will continue. System designers must consider the limits of human performance in both nominal and off-nominal conditions, to secure and maintain the operator's attention without exceeding their ability to interact and process. When system degradation prompts an automated reversion to lower	RAHS.1.1 RAHS.1.2 OP.1, OP.2, OP.3 DT.1, DT.2 OC.1, OC.3 IM.3

			system performance limits, automation-to-automation design integrity is critical. An appropriate allocation of human versus automation functions will decrease the possibility for automation complacency in highly automated environments, will allow the operator to successfully attend to and satisfy the most pressing tasks, and will free the operator from time-critical decisions reliably made by automation – resulting in fewer instances of inappropriate human intervention.	
EN-3122	2015	Reduced Controlled Flight into Terrain - Level 1	Controlled Flight Into Terrain (CFIT) is reduced through incorporation and integration of synthetic vision technologies and world-wide geospatial databases. Situational awareness enhancements utilize database, sensor, and hazard (terrain, traffic - surface and airborne, etc.) detection technologies merged with display symbology and precise Global Positioning System (GPS) navigational information to create synthetic views of the aircraft's external environment for display to the flight crew. Regional databases and integrity monitoring technologies provide (acquire, verify, and maintain) worldwide geospatial databases suitable for synthetic vision applications.	DDS.1.1 DDS.1.2 OP.1 EA.1, EA.2 SS.1, SS.2, SS.3 MM.1
EN-3127	2015	Reduce Airborne Icing-Related Incidents - Level 1	Reduce icing-related incidents through equipage of aircraft with icing detection and avoidance technologies, and icing tolerant technologies. Improvements are needed in icing computational tools, icing experimental methods, icing experimental databases, icing atmospheric characterization technologies, and icing education and training tools.	EA.1, EA.2 SS.1, SS.3, SS.4
EN-0109*	2016	Avionics - Surface Conflict Management	Aircraft equipage that will enable trajectory-based procedures used on the surface at high-density airports to expedite traffic and schedule active runway crossings. Aircraft will perform delegated separation procedures, especially in low-visibility conditions.	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 DT.2 EA.1, EA.2 SS.1, SS.2

EN-0101	2017	Avionics - Enhanced Obstacle Detection	Enhanced vision systems for acquisition of runway environment and obstacles, such as Forward Looking Infra Red (FLIR).	DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2, SS.3 MM.1
EN-2681	2017	Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 2	This enabler provides guidance, methodologies, and algorithms for weather assimilation into decision-making. This is accomplished through intermediate, crosscutting, foundational research such as: translation of weather's impact on operations, operational metrics development, determination of NextGen relevant weather information, basic mathematical research into optimization methodologies, operational research analysis, techniques for the presentation of probabilistic information to humans and automation, characterization of hazardous weather phenomena (e.g., estimation of aircraft-specific weather hazard levels, pilot likelihood to deviate, permeability of weather), and benefits pool estimation. This mid-term research will work with greater levels of weather uncertainty and longer look ahead times. It will extend the results in the en route and terminal domains and begin to produce useable results for weather assimilation in the Traffic Flow Management (TFM) domain and surface operations arena. Areas of particular focus include: working with increasing maturity of probabilistic forecasting; methods to translate greater weather uncertainty levels into impact; and advances in risk based decision-making.	DDS.1.1 DDS.1.2 EA.1, EA.2 OP.4 OC.2 SS.1, SS.3, SS.4 IM.1
EN-2830*	2018	Aircraft Systems - Low Visibility Alleviation	Enhanced onboard vision systems allow VFR-style operations (both ground and in-flight operations) in low visibility conditions	DDS.1.1 DDS.1.2 EA.1, EA.2 SS.1, SS.2, SS.3 DT.2 MM.1

EN-2860*	2018	Aircraft Systems - Volcanic Ash Alleviation	On board sensors and protection systems that improve the ability of the aircraft to avoid, exit, or endure atmospheric particulates.	SS.1, SS.3, SS.4
EN-3102	2018	Safety Risk Management Processes and Tools	Improvements to Safety Risk Management (SRM) processes and tools result from research into analysis methods, risk estimation techniques, fault management, and other aspects of SRM. Routinizing SRM processes and reducing the SRM cycle time will reduce the potential for recurrence of incidents and accidents from known risks.	FDS.2.1 IM.3
EN-2682	2021	Methodologies and Algorithms for Weather Assimilation into Decision-Making - Level 3	This enabler provides guidance, methodologies, and algorithms for weather assimilation into decision-making. This is accomplished through end state, crosscutting, foundational research such as: translation of weather's impact on operations, operational metrics development, determination of NextGen relevant weather information, basic mathematical research into optimization methodologies, operational research analysis, techniques for the presentation of probabilistic information to humans and automation, characterization of hazardous weather phenomena (e.g., estimation of aircraft-specific weather hazard levels, pilot likelihood to deviate, permeability of weather), and benefits pool estimation. This far-term research will expand upon the results in all domains in order to meet all NextGen goals for assimilation of weather into decision-making.	DDS.1.1 DDS.1.2 EA.1, EA.2 OP.4 OC.2 SS.1, SS.3, SS.4 IM.1
EN-0032*	2022	Avionics - Airborne Self-Separation	Development, validation, and implementation of aircraft technologies and procedures for airborne separation capability to meet requirements for all NextGen airborne separation applications (airborne self-separation airspace operations, including entry and exit, and delegated airborne separation operations in classic and TBO airspace).	RAHS.1.1 RAHS.1.2 OP.1, OP.2 OP.3, OP.4 DT.1 OC.2
EN-3059	2025	Increased Reliability and	As design guidelines are developed (continuous), implement and deploy technologies that reduce data acquisition,	EA.1, EA.2

		Accuracy of Data and Information - Level 2	processing and display errors. These technologies will increase the reliability and accuracy of data/information, with a performance measure of reduced data acquisition, processing, and display errors. (Level 2 - difficult, system level, new design)	
EN-3061	2025	Improved Operational Decision Aids - Airborne Level 2	As design guidelines are developed (continuous), implement and deploy technologies that reduce time required to optimize decisions and reduce the number of hazards encountered. These technologies will improve the awareness and mitigate response to airborne events and hazards. The performance measures are reduced time required to optimize decisions and a reduced number of hazards actually encountered. (Level 2 - difficult, system level, new design)	RAHS.1.1 RAHS.1.2 DDS.1.1 DDS.1.2 OP.4 EA.1, EA.2 OC.2 SS.1, SS.2, SS.3 SS.4, SS.5 IM.1
EN-3123	2025	Airborne Weather Information Technologies- Level 1	Reduce weather-related incidents through equipage of aircraft with cockpit weather system technologies for enhanced situational awareness & decision-making. Aircraft are equipped with airborne weather reporting sensor technologies, weather information datalink systems technologies for ground-to-air dissemination, airborne weather reporting data link systems for air-to-ground and air-to-air dissemination, weather hazard detection, monitoring, warning, and alerting technologies for hazards including turbulence, icing, restrictions to visibility, volcanic ash, cross-winds, wind shear, etc.	DDS.1.1 DDS.1.2 OP.2 EA.1, EA.2 SS.1, SS.2 SS.3, SS.4
EN-3124	2025	Reduced Controlled Flight into Terrain - Level 2	Level 2 builds upon Level 1 successes. Controlled Flight Into Terrain (CFIT) is reduced through incorporation and integration of next generation situational awareness enhancements. Situational awareness enhancements utilize database, sensor, and hazard (terrain, traffic - surface and airborne, etc.) detection technologies merged with display symbology.	DDS.1.1 DDS.1.2 OP.1 EA.1, EA.2 SS.1, SS.2, SS.3 MM.1

| EN-3125 | 2025 | Airborne Weather Information Technologies-Level 2 | Level 2 builds upon Level 1 successes. Reduce weather-related incidents through equipage of aircraft with next generation cockpit weather system technologies for enhanced situational awareness & decision-making. Aircraft are equipped with enhanced airborne weather reporting sensor technologies, weather information datalink systems technologies for ground-to-air dissemination, airborne weather reporting datalink systems for air-to-ground and air-to-air dissemination, weather hazard detection, monitoring, warning, and alerting technologies for hazards including turbulence, icing, restrictions to visibility, volcanic ash, cross-winds, wind shear, etc. | DDS.1.1 DDS.1.2 OP.2 EA.1, EA.2 SS.1, SS.2 SS.3, SS.4 |
| EN-3128 | 2025 | Reduce Airborne Icing-Related Incidents - Level 2 | Reduce icing-related incidents through equipage of aircraft with icing detection and avoidance technologies, and icing tolerant technologies. Improvements are needed in icing computational tools, icing experimental methods, icing experimental databases, icing atmospheric characterization technologies, and icing education and training tools. | SS.1, SS.3, SS.4 |

* NASA is the identified Office with Primary Responsibility (OPR) or Supporting OPR for this Enabling Technology